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EXPERIMENTAL ANALYSIS OF HEAT TRANSFER AND FRICTION FACTOR IN A ROUGHENED SOLAR AIR HEATER USING STAGGERED INCLINED DISCRETE RIB ARRANGEMENT

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ABSTRACT

The solar air conditioner (SAH) utilizes barbell roughness to improve heat transfer. Experimental evaluations are complete on friction factor and the heat transfer in the retina, and this is sometimes roughened from the ribs that were probable. The ribs were discretized by making a gap at distinct positions (not in line) on tracking and top edge in consecutive ribs (in a staggered arrangement). The rib roughness has relative roughness pitch since 8.0, rib mix of comparative gap positions is varied from 0.3 & 0.1 to 0.3 & 0.4 and mass flow rate varies from 3000 to 14000 and rib relative gap width as 1.0. The increased advancement in Nusselt number is obtained in 2.62 times together with the friction factor is obtained in 2.91 times, respectively, in contrast to a smooth duct. Maximum thermohydraulic performance (THP) parameters are renowned for its own rib combined relative gap rank of 0.3 and 0.3.

KEYWORDS: Friction Factor, Reynolds Number, Relative Gap Width, Combination of Relative Gap Position, Nusselt Number & Thermohydraulic Performance (THP)

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Original Article

1. INTRODUCTION

The operation of SAHs is decreased because of the bad heat exchange limit between the absorber plate and working liquid, for example, the air. The unpleasantness component divides the thermal edge causing heat transfer to enhance. But this also increases friction reduction resulting in increased pumping power requirements from blower or fan. To reduce friction reduction and draining power, turbulence should be produced in the area across the absorber surface to make sure that divide the laminar sub-layer. Because of the use of artificial roughness in the SAH, many investigations [2-5] are finished designed to improve the cooling of this length of their antenna. Han et al., [2] examined the impacts of the kind of the ribs, pitch proportion of the elevation to the rib coefficient of friction and angle of attack and heat transfers characteristics of a square duct along with two sides of the rough dividers. [3] it has like been discovered that due to the interaction of the primary and secondary flows inducing the marketplace of transverse rib in a continuous manner by the probable rib square duct, the walls of the ribbed there is higher turbulence. Aharwal et al., [9] experimentally examined the impact of hot transfer characteristics and the coefficient of friction using a distinct key likely rib from the square-foot SAH. Aharwal et al., [10] they investigated the geometry of unpleasantness as probably rib working with a gap to improve heat transfer in the absorber plate of the SAHs.

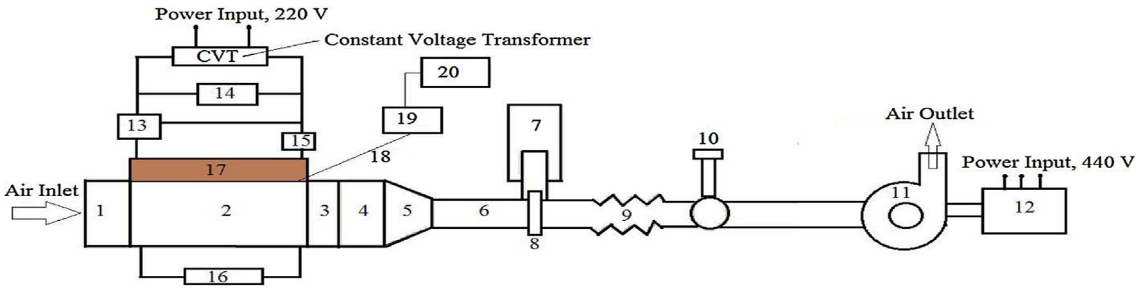

Figure 1: Demonstrates the Schematics Diagram of the Test Set-up.

1. Inlet section, 2. Of atmosphere. Section for the 3. Mixing 4, of atmosphere. Exit part 5, of atmosphere. Evaluation change 6, Section. 7, iron pipe. 8, manometer. 9, plate. 10, pipe. Airflow controls valve, 11. Blower for atmosphere, 12. suck. Electric engine 13. 14 or variac, auto-transformer. 15, Analog or digital voltmeter. Digital or 16, analog ammeter. Digital or pressure 17, measurement apparatus. Ability 18, Warmer. 19, thermocouples cable. Digital data (information) tracker, 20. A computer for advice recordings.

They Boost the gap positions and gap width in the rib and noticed that the maximum THP performances value was acquired to acquire its own rib gap width of rib and one gap status of 0.25. In the previous studies, nearly all the ribs are discretized by making the gap in an immediate line manner. However, no investigations are made for inclined ribs at which openings are produced from the conjugative ribs in a zig-zag manner (not in a direct line) as shown from the proposed roughness geometry in previous studies [4, 7, 3, 6, 8, 9 and 10]. This investigation was undertaken as much as select the ideal place of the several openings structures (which are not consistent) and capability to raise the heat transfer from the absorber plate of SAH to the fluid. This analysis can help to learn the dimensions and position of this gap during the discretization of a rib that is inclined in order to boost the performance compared together with the non-discretized rib. Within this work consider, the experimental analyses of those performances of this SAH duct are completed, using absorber plates together with artificial unpleasantness as a staggered inclined distinct barbell together with gap structures. The variants of friction variables and Nusselt no. In the type of the rib unpleasantness parameters, where the gap places and gap diameter have been analyzed to look into the THPs of these systems to comprehend the advantages of current chosen rib unpleasantness geometry.

2. TEST SET-UP

It is engine section, the round pipe having an orifice plate to quantify flow rate and a test section. There is A variac used to restrain voltage and current, which offers heat flux. Voltage are used to gauge the present. The cables are used to measure inlet, outlet and plate depth. There is an information device used to determine the temperature. An manometer can be used to measuring the pressure drops. Stress fall along the plate was quantified with all the stress lever.

Table 1: The Values of the Parameter used in this Roughness Geometry

Sl. No.	Parameters	Values
1	Reynolds Number (Re)	3000–14,000
2	Relative roughness pitch (p/e)	8.0
3	Relative roughness height (e/D_h)	0.045
4	Rib height (e) & Rib width (b)	2mm
5	Hydraulic diameter	44.44
6	Duct aspect ratio (W/H)	8.0
7	Angle of attack (α)	30°
8	Heat flux	900 W/m^2
9	Relative gap width (g/e)	1.0
10	Combination of relative gap position (dt/W & dl/W)	0.3 & 0.1 to 0.3 & 0.4

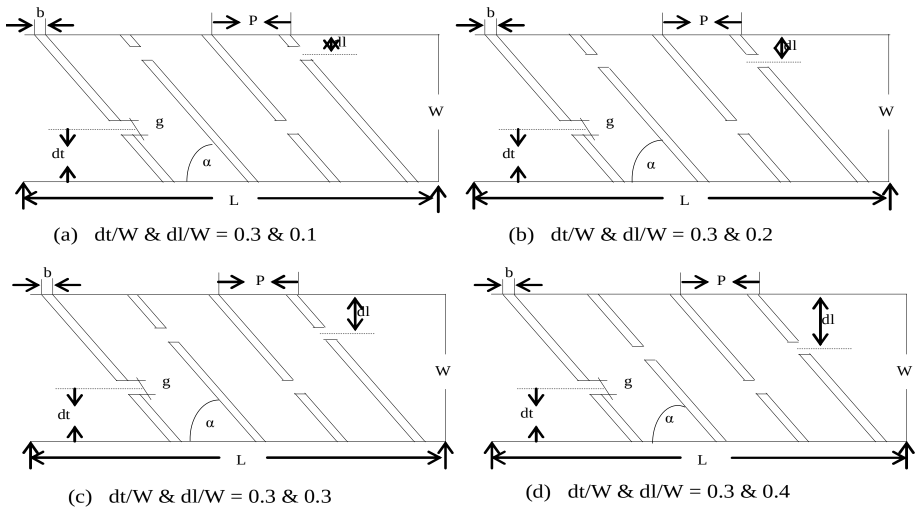

Figure 2(a-d): Demonstrates the Discretization of Ribs by creating Gaps at various Gap Positions of 30° Inclined Ribs.

3. RIB ROUGHNESS GEOMETRY AND RANGE OF PARAMETERS

The unpleasantness parameter for analysis of proposed rib geometry especially the rib which has been likely is shown in Table 1. In light of the ideal values of this parameter, declared in the task of literature [9, 10], the rib roughness pitch (p/e) correlation and rib angle of attack are chosen as 8.0 and 30° respectively. Bearing in mind the ending goal to find out more about the consequences of gap status on the advancement of the heat exchanger and coefficient of friction, the rib mix of varied gap places (dt/W and dl/W) are varied between 0.3 and 0.1 to 0.3 and 0.4 times of the rib breadth of the channel from Trailing and leading edges of the ribs, whereas the rib distinct gap diameter (g/e) is kept up. The ranges of Reynolds number and assorted unpleasantness tallness (e/Dh) are chosen due to their requirement for a SAH [11]. The heated plate is 5mm thick aluminum plate of 1.5m × 0.2m (length 1.5m and diameter 0.2m) are used as absorber plates and bottom surface of the plate was provided the artificial unpleasantness as a staggered inclined distinct rib of an aluminum plate in the CNC machining process and plus a gap on rib has been created by means of a milling machining. The schematic structure of the roughened plate is shown in Figure 2 (a-d).

4. DATA REDUCTION

The worth of air and plate temperature have been Projected For flow rate and heat flow in a condition that is constant. The transaction, nusselt no. With the factor Information obtained. It assists in finding the effects of various parameters on Nusselt no. And grinding factor using the formulae.

$$m = C_d \times A_o \times [2 \times \rho \times \Delta P_o / (1 - \beta^4)]^{0.5} \tag{1}$$

$$V = m / \rho \times W \times H \tag{2}$$

$$Q_u = m \times C_p \times (T_o - T_i) \tag{3}$$

$$h = Q_u / A_p \, (T_{pav} - T_{fav}) \tag{4}$$

$$Re = V \times D_h / \nu \tag{5}$$

$$Nu_r = (h \times D_h) / \kappa \tag{6}$$

$$f_r = [2 \times (\Delta P)_d \times D_h / (4 \times \rho \times L \times V^2)] \quad (7)$$

$$Pr_r = (\mu \times C_p) / \kappa \quad (8)$$

$$St_r = Nu/(Re \times Pr) \quad (9)$$

$$\eta = (Nu_r / Nu_s) / (f_r / f_s)^{1/3} \quad (10)$$

5. RESULTS

5.1. Validity Test

The Nussel's Contrast. And factor determined by a Test ran on a channel that has been smooth was accessed through the Dittus Boelter requirement because of the Nusselt. And was done throughout the Blasius Requirement for the factor that has been grinding. These equations are supplied below:

Dittus Boelter condition

$$Nu_s = 0.023 \times Re^{0.8} \times Pr^{0.4} \quad (11)$$

Modified Blasius equation

$$f_s = 0.85 \times Re^{-0.5} \quad (12)$$

The comparison between the purchase price of Nusselt as well as the evaluation value. And grinding factor on the surface is exhibited in Figure 4 and Figure 3. It has been noticed. And grinding factor for smooth duct got by experiments is at least as nice to the values estimated by Equation (11) and Equation (12) respectively. Considering that the value of the Nusselt. And grinding factor, there are somewhat close understandings because of its evaluated worth, the legitimacy of the experimentation is guaranteed.

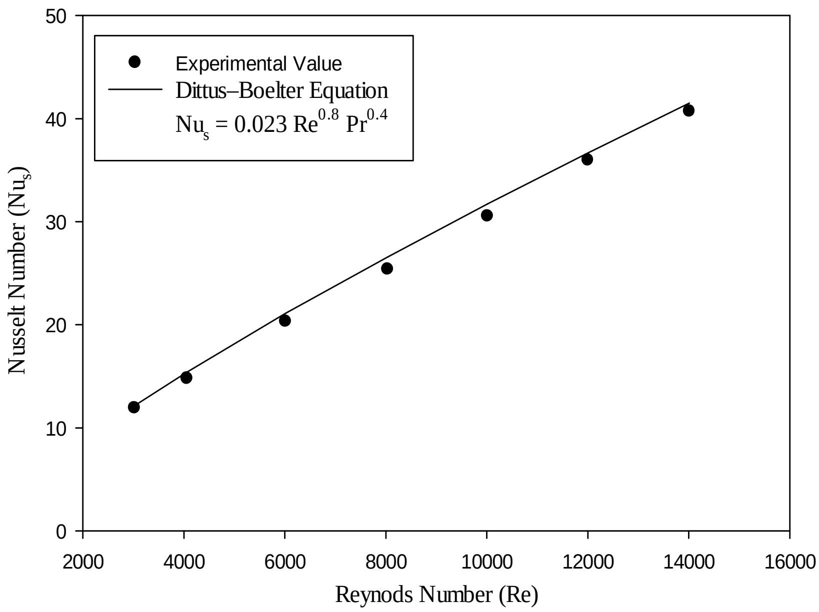

Figure 3: Demonstrates the Comparison of the Test Value and Theoretical Value of the Nusselt no. for the Smooth Surface Plate.

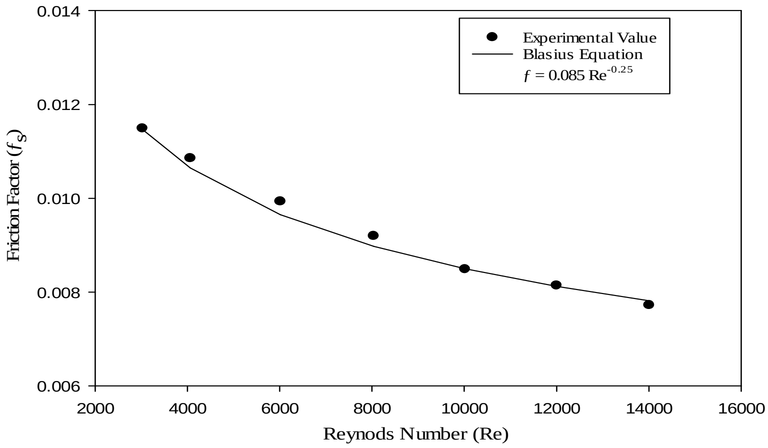

Figure 4: Demonstrates the Comparison of the Test Value and Theoretical Value of the Grinding Factor for the Smooth Surface Plate.

5.2. Impact of Reynolds Numbers

Figure 5 shows the variations of the Nusselt no. Reynolds numbers Growing. The Nusselt's worth. Are seen the combinations of different gap areas of 0.3 & 0.3 and it's most economical for its own combo of various gap rank of 0.3 & 0.1. To see the effects of rib artificial unpleasantness concerning the improvement of sexy exchange in comparison with this of with no synthetic unpleasantness constructions (smooth surfaces), the proportion of the Nusselt no. of roughened surfaces in addition to the Nusselt no. Of surfaces (Nur/Nus) for distinct value of those unpleasantness parameters since the Reynolds number has revealed in Figure 6. Proportion is most effective of roughened as a gap in a way in ribs compared with of the ribs for its arrangement. There is a gap between roughened plate advice due to turbulence caused by rib roughness. The rib roughness divides the laminar sub-layer causing turbulence that fosters exchange that is hot. At Reynolds number, the gap between the smooth and coarse plate is less, but it is very important for the value of the Reynolds numbers.

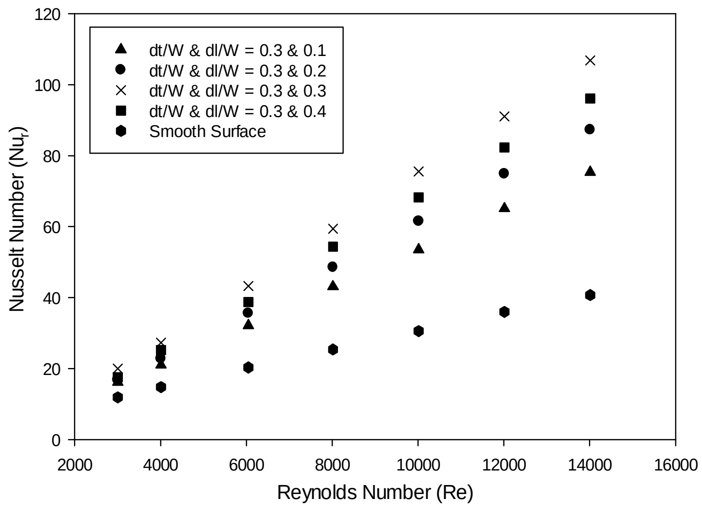

Figure 5: Demonstrates the Variations of Nusselt no. along with Reynolds Numbers for different Gap Positions.

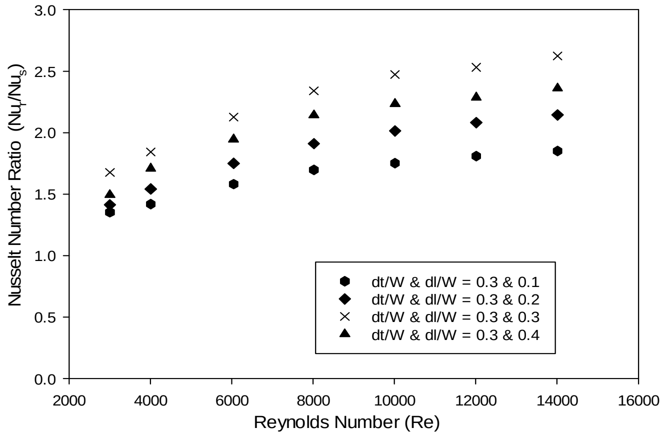

Figure 6: Demonstrates the Variations of Nusselt no. Proportion along with Reynolds Numbers for different Gap Positions.

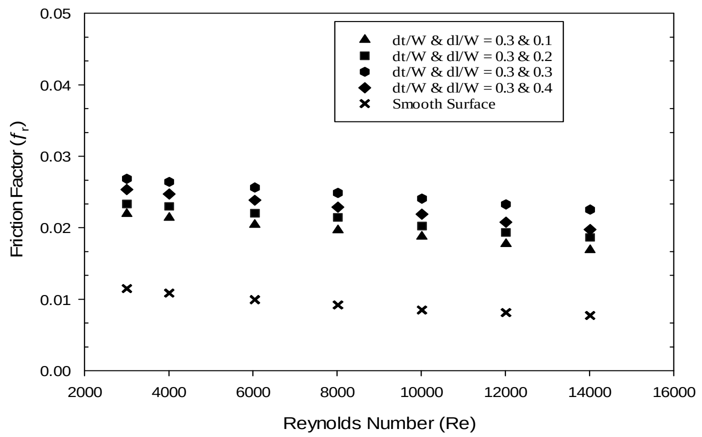

Figure 7: Demonstrates the Variations of Grinding Factor along with Reynolds Numbers for different Gap Positions.

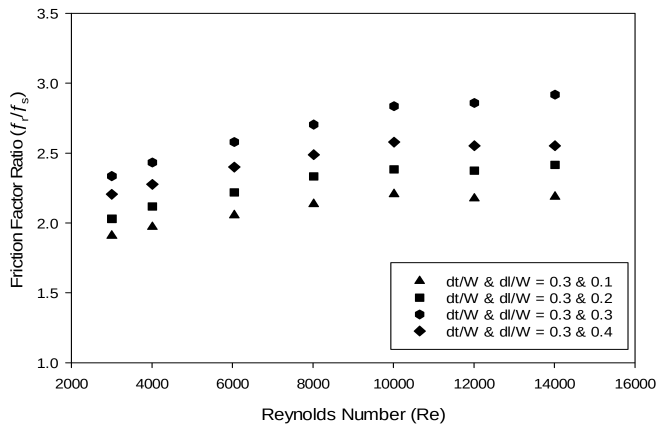

Figure 8: Demonstrates the Variations of Grinding Factor Proportion along with Reynolds Numbers for different Gap Positions.

The version of factor is as lines. The grinding factor is greater for its mix of various gap areas of 0.3 and 0.3 and its lowest because of its own combo of various gap areas of 0.3 and 0.1. A higher scattering whereas suggested geometry shrunk barbell and grinding factor due to flow acceleration receives the grinding factor due to the scattering of flow and circulation acceleration. Figure 8 illustrates the variation of this grinding variable ratio (fr/fs) and all the Reynolds number because the combo of the various gap place. It is inclined to be noted that the variety of the grinding factor ratios varies by 1.90 into 2.91 the proposed ranges of the Reynolds numbers. The most value of the grinding factor ratio is celebrated because of its mix of the variety of gap area of 0.3 & 0.3 whereas its minimum values are celebrated for its combo of various gap ranking of 0.3 along with 0.1.

5.3. Thermo-hydraulic Performance

The Thermo-hydraulic Functionality (THP), Lewis [12] Offered a THP parameter Called the Efficacy parameter 'η', the Requirement for precisely the same Indices Electricity Requirement, which assesses the Progress, in comparison with the Smooth duct in the heat transport of a roughened duct and may be distinguished as

$$\eta = (St_r / St_s) / (f_r / f_s)^{1/3} \tag{13}$$

Over solidarity, a value of this parameter ensures that the productivity of utilizing the upgrade gadget and might be used to discover the sum of actions arrangement of activity's performance to choose the ideal. The value of this parameter is shown in Figure 9 because of its unpleasantness geometry explored in this work. It is noted that parameters' values are by and big greater for inclined ribs in comparison without ribs under illness that was relative. It has a tendency to be considered the THP parameter varies from 1.01 to 1.83 the projected range of the Reynolds number. The maximum values for this parameter are renowned for combining the relative gap rank of 0.3 and 0.3 in many Reynolds number value.

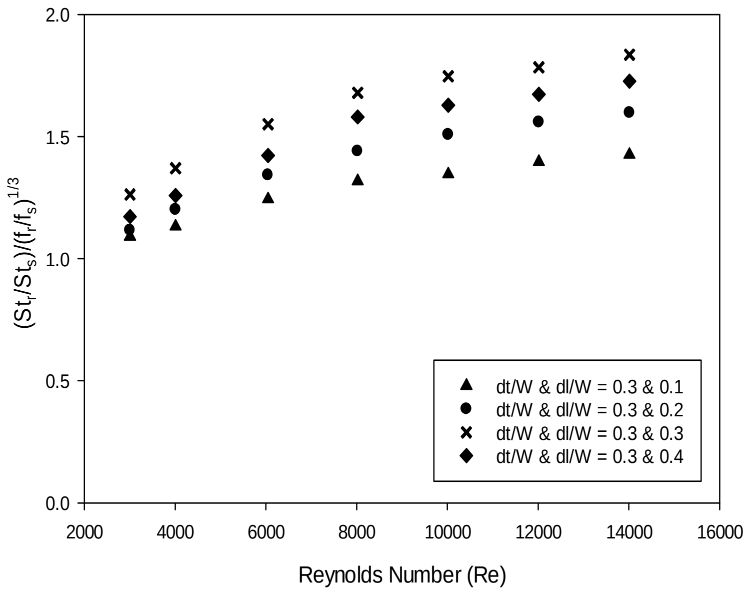

Figure 9: Demonstrates the Variations of THP along with Reynolds Numbers for different Gap Positions.

6. CONCLUSIONS

The Decisions shown from these investigations are-

- The Nusselt number shows tendencies with increasing Reynolds number. Proposed geometry especially the staggered inclined different barbell suggests the most progress in Nusselt number is detected that the combinations of gap rank of 0.3 and 0.3 compared with various mixtures of relative gap positions.
- Proposed geometry especially the staggered inclined different barbell suggests the most progress in friction factor is detected that the combinations of gap rank of 0.3 and 0.3 compared with various mixtures of comparative gap rankings.
- Indicated geometry has performance. The maximum value for proposed geometry is 1.83 the combinations of gap position of 0.3 and 0.3 in contrast with other mix of comparative gap areas.

Nomenclature

- A_o Cross-section area of orifice, m^2
- A_p Area of the absorber plate, m^2
- A_s Area of the smooth plate, m^2
- C_d Coefficient of discharge of orifice
- C_p Specific heat of air at constant pressure, J/kg K
- D_h Hydraulic diameter of the duct, m
- D_p Inside diameter of the pipe
- d/W Relative gap position
- dl/W Leading edge
- dt/W Trailing edge
- g Gap width, m
- H Depth of duct, m
- h Convective heat-transfer coefficients, W/m^2 K
- $(\Delta h)_o$ Difference of manometric fluid levels in U-tube manometer, m
- $(\Delta h)_d$ Differences of water column levels in micro-manometer, m
- k Thermal conductivity of air, W/m K
- m Mass flow rate, kg/s
- P Pitch of the rib, m
- ΔP_o Pressure drop in the duct, P_a

- Q_u Useful heat gain rate, W
- T_i Inlet temperature of the air, K
- T_m Mean temperature of the air, K
- T_o Outlet temperature of the air, K
- T_p Average plate temperature, K
- V Velocity of air, m/s
- W Width of duct, m

Greek symbols

- β Ratio of orifice diameter to pipe diameter
- η_{th} Thermo-hydraulic parameter efficiency
- ρ Density of air, kg/m^3
- ρ_m Density of manometric fluid, kg/m^3
- ρ_w Density of water, kg/m^3
- μ Dynamic viscosity, kg/m-s
- υ Kinematic viscosity, m^2/s

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